Study the Relation of dye laser pulses with its concentration for the Rhodamine B dye.

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ABSTRACT*--The work includes the study of some optical and physical properties of rhodamine B dye in ethanol solvent at different concentrations (1x10-5 , 2x10-5 , 4x10-5 , 1x10-4 , 5x10-4, 1x10-3, 5x10-3 mol/L) at room temperature, study and calculation the density and energy of the productedlaser . The UV absorption spectra and fluorescent emission intensity of Rhodamine B (Rh B) dye were determined at different concentrations. The results showed that the intensity and wavelength of the peak of the absorption spectrum for rhodamine B depends on* ***increasing*** *the concentration of the dye leading to increased interference between the absorption spectrum and fluorescence. It was found that in the case of rhodamine B dye, the laser intensity decreased, if the concentration of rhodamine B increased.DYE output energy, full-width-at-half-maximum (F.W.H.M) , intensity and efficiency was calculated for different concentration of RB at maximum wavelength and we got the following at the highestconcentration:(15.5mJ,8.57nm,9793.27counts,44.03%) respectively where the maximum energy was included (35.2mJ).*

Keywords*-- Dye Rhodamine B, Quantum Efficiency, Nd:YAG laser, dye laser and ethanol solvent.*

I. INTRODUCTION

Since the advent of lasers in 1960, the tunable laser has been always an important part of laser research. The core of tunable laser is tunable laser medium with broadband energy level structure. The most widely used tunable laser medium is organic dye. By choosing different types of laser dye, the output laser wavelength could be covered from near-ultraviolet, visible light to near-infrared [1,2,3]. Nowadays, the Dye lasers used in many applications as spectroscopy, medical, photochemistry[4]. Rhodamines dye has various applications in many scientific branches, where used as laser dyes, fluorescence standards (for quantum yield and polarization), pigments and as fluorescent probes to characterize the surface of polymer nanoparticles, fluidity of lipid membranes as well as in the detection of polymer-bioconjugates, studies of adsorption of oligonucleotides on latexes, studies of structure and dynamics of molecules, single-molecule imaging and imaging in living cells [6,7]. The Quantum efficiency is the ratio of the number of emitted photons to the number of absorbed photons (or The fluorescence quantum yield is defined as the ratio of the number of photons emitted to the number of photons absorbed or we can written as [8][9][10].

$$QY = number\ of\ photons\ emitted/number\ of\ photons\ absorbed$$

Broadband dye lasers typically have bandwidth or full-width half-maximum (FWHM) determined only by organic dyes are used as a laser gain medium. The organic dye's complicated molecular structure generates a

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tightly-spaced energy spectrum which causes a "broadband" response to the excitation of the molecules [11], [12], [13]. In this work we used RB dye were dissolved in ethanol solvent for different concentration (1x10-5 , 2x10-5 , 4x10-5 , 1x10-4 , 5x10-4, 1x10-3, 5x10-3) mol/l, and study spectral properties of them.The purpose of this study was to gain understanding of the behavior of bandwidth dye lasers created with RB dye and to allow others to use the behavior characterized to make a laser of their desired characteristics.

II. THE EXPERIMENTAL PART:

The dye materials used in this research are shown in table (1)

Table (1) : Materials used and their specifications

Materials	Specifications	
RB dye	Constitution	2-[6-(Diethylamino)-3-(diethylimino)-3H-xanthen-9-yl] benzoic acid- Rhodamine 610
	Moleculare formula	$C_{28} H_{31} Cl N_2 O_3$
	Moleculare weight	479.02 g/mol
	Color	Appearance when buying: green, Crystalline solid Appearance when diluted with ethanol solvent: red and its gradients Appearance when pumping: orange
	$\lambda_{Abs\ (max)}$ in ethanol	550 nm
	$\lambda_{Flu\ (max)}$ in ethanol	625nm
Ethanol	Molecular formula	C_2H_5OH
	Appearance	Colorless liquid
	Molar mass	46.07 g / mol
	Purity	99.9%

Preparation of dyes using solvents

To weigh or prepare any dye, you should not forget or neglect to wear protective clothing, masks, and gloves when handling dyes and solvents. Studies have proven how dangerous these dyes and solvents are, and we should not forget that the aim of these studies is for the benefit of mankind.

The rhodamine B dye or any other dye to be prepared is prepared as follows:

1- (in the solid state of the dye) the dye is weighed using the sensitive scale after obtaining the required weight. The dye is dissolved by using ethanol solvent with purity (99.9%) or any other suitable solvent in the glass flask of the required size and according to the concentration to be prepared to obtain the mother sample according to the relationship The following:

$$\mathbf{W} = \frac{\mathbf{Mw\ X\ VX\ C}}{\mathbf{1000}} \ldots (1)\ [14]$$

W: The weight of the dye to be prepared (R_B=0. 5988 gm)

M_W : the molecular weight of the dye to be prepared (*$R_B M_W$ = 479.02*gm/mol)

V: solvent volume (250 ml)

C: Molar concentration of the mother pigment to be prepared (C.R_B=5X10^{-3}mol/l)

2 - (In the liquid state of the dye) after preparing the mother sample, it is shaken in an accidental manner and we consider it the first concentration, then we start drawing from it to prepare a second lighter concentration, then we withdraw from the second to prepare a third concentration, and so on ... according to the dilution relationship:

$$C_1 V_1 = C_2 V_2 \ldots(2) [15]$$

C_1 : Primary Focus (High)

C_2 : second focus (low)

V_1 : first volume before dilution

V_2 : Volume 2 after dilution (volume of beaker to be prepared)

In this research, concentrations(*10^{-3}*-10^{-5}) *were selected according to previous studies of Rhodamine B dye*

Fig.1.Rhodamine B dye for different concentrations

III. THE EXPERIMENTAL SETUP FOR GENERATION DYE LASER

Illustration image the laser setup was shown in Fig. 2. The second harmonic generation (SHG) of Q-switched Nd: YAG laser operating at 1064 nm with repetition rate of 10 Hz . Generation of Dye laser Simply consisting of one Concave mirror and lens with laser dye(RB) as gain medium was the Generation by optical pumping for spectral study and to obtain the best output power and the shortest pulse at the best operating conditions. RB solutions were put into a quartz cuvette with 10mm optical length. The output spectrum was detected by aspectrometer (OceanOptics) . The input-output curve and full width at half maximum (FWHM) of the output spectrum were plotted in Fig(), and efficiency could be calculated from (η=Eout/Ein) ,where Eout and Ein

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represented the output and the input energy shown in the table() .Ethanol solvent was chosen as the best solvent for the rhodamines family .

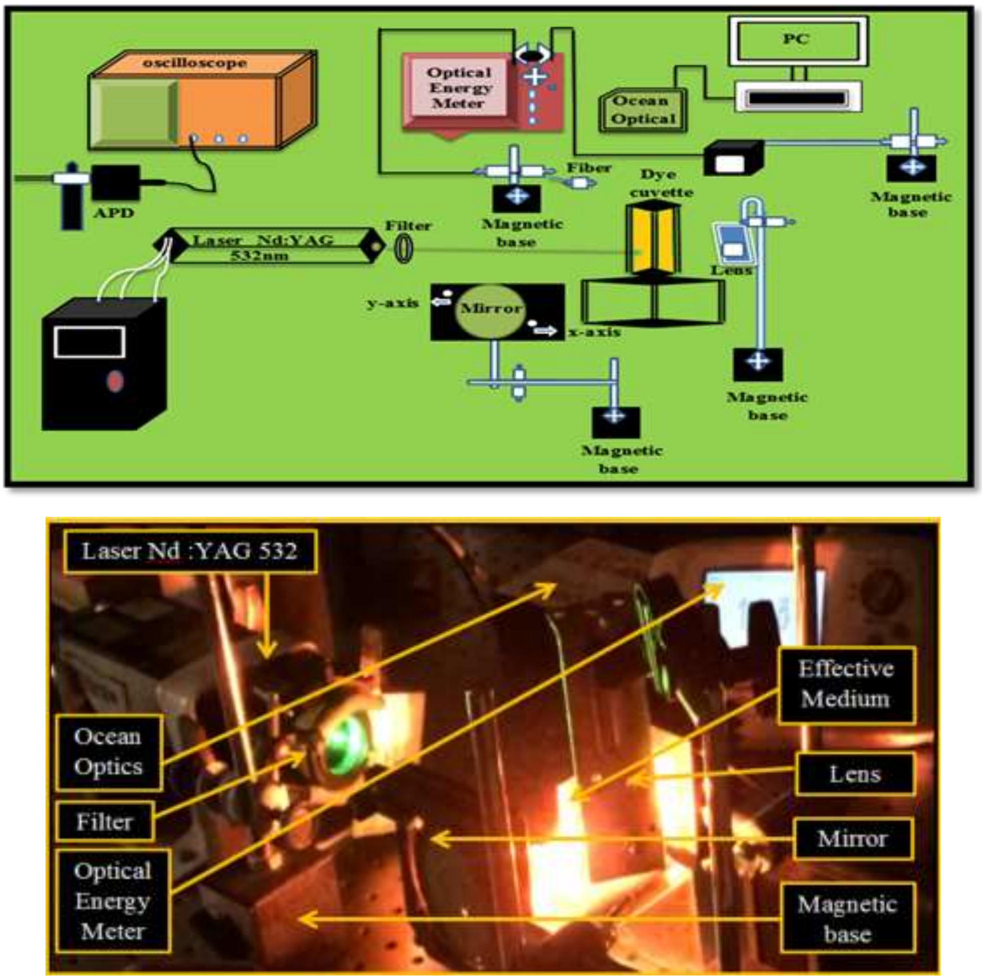

Fig.2.Illustrative image for dye laser generation

The experiment was prepared and the readings are as follows:

- Seven concentrations were selected for work.
- The following devices are operated:

1- Nd:YAG Laser System (CFR 200 and CFR 400).

2- Optical Power/Energy Meter.

3- Ocean Optics HR (4000) High Resolution Fiber Optic Spectrometer.

4- Avalanche Photodetectors (Model APD110A2).

5- TDS 2012 Oscilloscope.

- The cuvette is filled with Rhodamine b dye when working on each concentration.
- For each concentration the following is read:

1- The laser pulse generated by the dye by Avalanche Photodetectors (APD).

2- the exterior spectrum is measured by a spectrum analyzer.

3- Several energy measurements are determined on the Nd: YAG laseras follows:

(power 2,4,6,8,10). Then the reading of each measurement is taken as real energy when setting the energy meter, and in return the resulting spectrum is taken through the spectrum analyzer.

Table 2: The stock shift between fluorescence and absorption of RB at different concentrations.

Fig.3	Dye concentration (mole/l)	Absorption λ_{max}(nm)	Abs.	Fluorescence λ_{max}(nm)	Intensity (a.u.)	Stock shift (nm)
A	$1x10^{-5}$	550	0.871	565	999.9491577	565-550=15
B	$2x10^{-5}$	545	1.607	562	999.9802246	562-545=17
C	$4x10^{-5}$	545	2.467	562	1000.020691	562-545=17
D	$1x10^{-4}$	530	3.015	586	982.5301514	586-530=56
E	$5x10^{-4}$	530	3.074	604	353.5133667	604-530=74
F	$1x10^{-3}$	530	3.125	610	129.1325684	610-530=80
G	$5x10^{-3}$	530	3.275	625	82.03205872	625-530=95

IV. RESULTS AND DISCUSSION:

The absorption and fluorescence spectra of RB dye with concentrations (1x10-5 , 2x10-5 , 4x10-5 , 1x10-4 , 5x10-4, 1x10-3, 5x10-3) mol/l, are shown in the figure (3), where thefluorescence spectrum shifted to red shift (longer wavelength) with increasing the concentration and the absorption spectrum shifted to blue shift (short wavelength) this applied with Bear Lambert Law . Table (2) shows the absorption, fluorescence λmax (nm) ,Absorbance,Intensity and stock shift at different concentrations.From the Figure(3) we can observed that (dye RB) solution absorption spectrum has a spectral range at wavelength range between (550 nm -530nm).For lowerconcentration ($1x10^{-5}$M) the maximum absorption appears at wavelength (550nm) and red shifted by approximately (15 nm), for concentration ($2x10^{-5}$ M)the maximum absorption appears at wavelength (545 nm) and red shifted by approximately (17nm), for concentration (4x10-5 M) the maximum absorption appears at wavelength (545nm) and red shifted by approximately (17 nm), forconcentration ($1x10^{-4}$ M) the maximum absorption appears at wavelength (530 nm) and red shifted by approximately (56 nm), for concentration ($5x10^{-4}$ M) the maximum absorption appears at wavelength(530 nm) and red shifted by approximately (74nm),forconcentration ($1x10^{-3}$ M) the maximum absorption appears at wavelength (530 nm) and red shifted by approximately (80 nm), for higher concentration ($5x10^{-3}$ M) the maximum absorption appears at wavelength (530 nm) and red shifted by approximately (95nm). The absorption and fluorescence shift for samples are shown in Figure (3). Concentration affects the energy state where the higher the concentration the more particles per unit of volume.When the concentration increases, the Stokes shift will increase, and this will decrease the overlap

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between the emission spectrum and absorption and this case reduce self-absorption process notice table (2) and figure (3).With an increase in the concentration of rhodamineB dye, the width of the absorption curve increases and the width of the emission curve decreases note figure (3). Figure (4)(A) show the increased concentration caused a shift in the fluorescence wavelengths due to the excimer or dimmer formed in solutions by collision diffusion processes, leading to a decrease in the quantum efficiency, since its fluorescence causes an shift towards the longest wavelength of the “red wavelengths” at (550) nm. the change in the concentration of rhodamine B affects the fluorescence spectra as shown in figures (4)(B) .The wavelength, spectral shape, and efficiency of the laser are affected by every component of the laser. Components of the laser tested and characterized in this section are: dye type and concentration, the transmittance of the spectrally selective optics placed within the cavity, pump energy (fluence), and age of the dye solution. The output of the laser changes with age whether the gain medium is pumped by laser excitation light or not[16].The Rhodamine dyes with emission within the desired spectral range (590-610 nm) Solutions of these dye in ethanol yielded a maximum FWHM of 8.57 nm. This result was expected because FWHM in Ref [16] using the R610 in methanol solvent on his own was a maximum FWHM 7.2 nmnotice table (3). The pulse signal was taken on the Oscilloscope at different concentrations of rhodamine dye . The table (4)showsthepulse shapes , concentration, pulse duration, voltage, and frequency.Notice the figures (5,6,7)respectively the increased F.W.H.M,Intensity and Energy with concentration increasesat constant SHG Nd: YAG Input Energy (35.2mJ) .The concentration increases the efficiency of the laser by increasing the number of molecules available for stimulated emission. This trend continues until the number of molecules quenches the available excitation energy. Concurrently, the same re-absorption/re-emission effects that cause the red shift of the spectra with dye concentration [16][17] [18] also decrease the efficiency.Note the table (5) and figure (8) when concentation increases,dye output Energy increases , Energy Conversion efficiencyandvice versa .

Figure (3):Draw the absorption and fluorescence spectrum at different concentrations

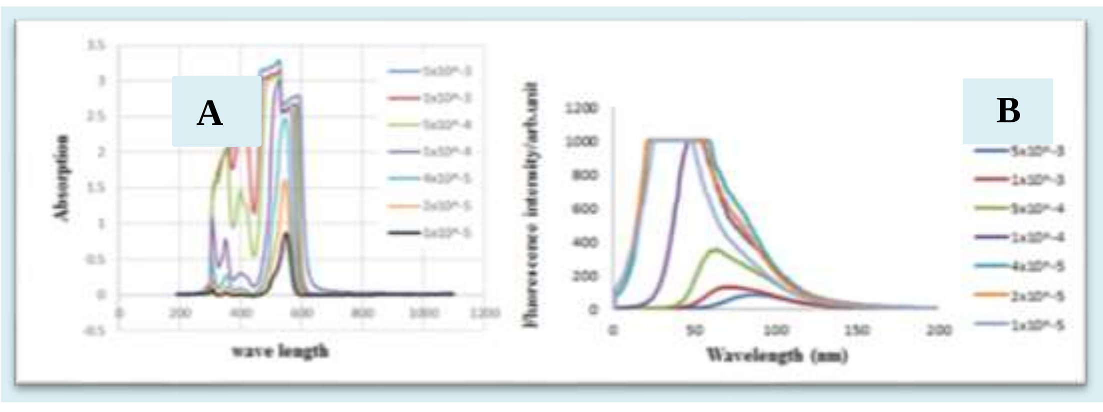

Fig.4.Allabsorption and emission measurements of the dissolved RB dye in ethanol at different concentrations.

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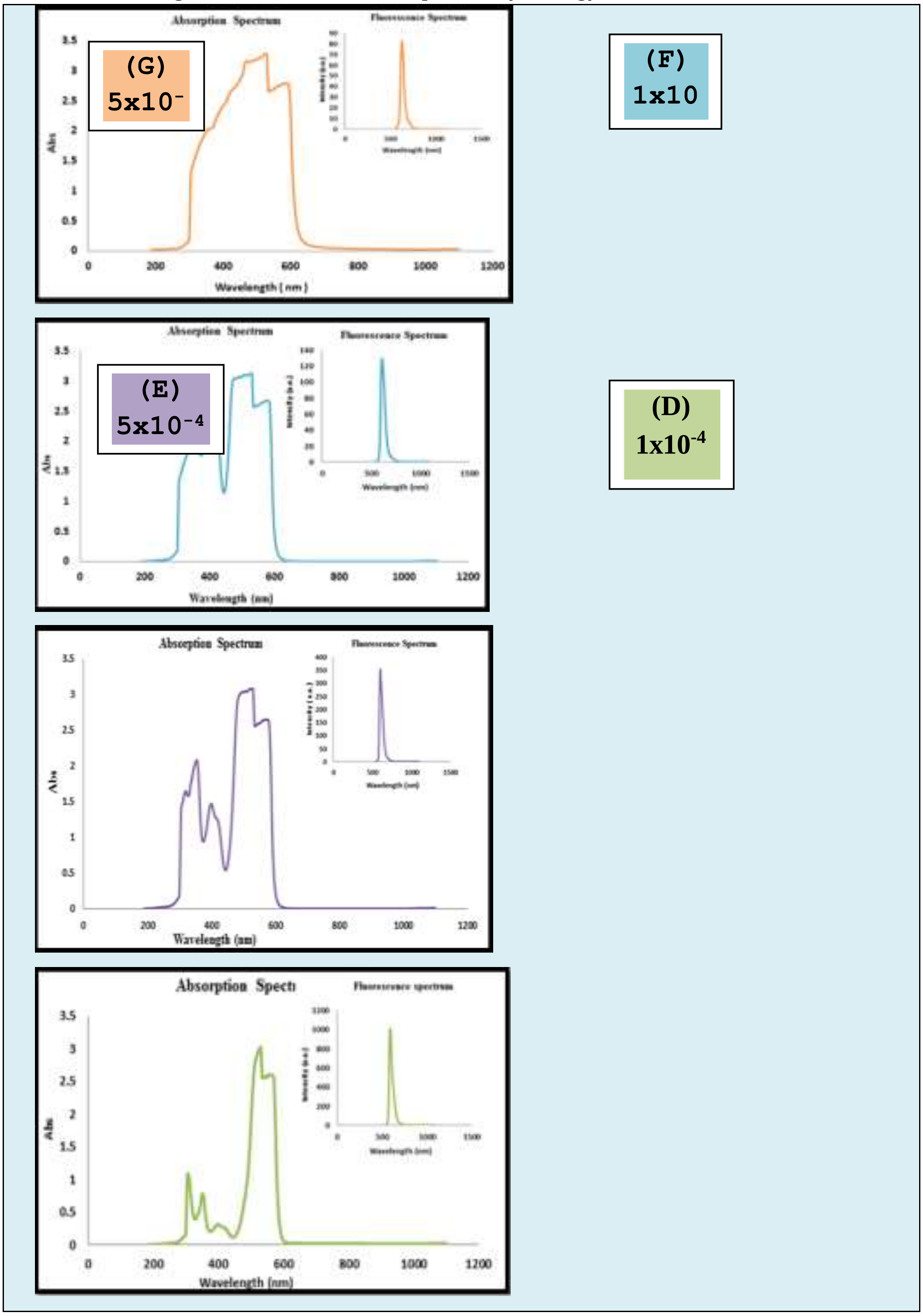
Table 3: The values and figures at work on laser setup Intensity, Energy, F.W.H.M for different concentrations at Laser



Spectrum λmax

Fig	Concentration (M)	Laser Spectrum λmax	Intensity (counts)	Energy (mJ)	F.W.H.M (nm)
A	$1x10^{-5}$	603.53	182.55	11.7	603.79-603.26=0.53
B	$2x10^{-5}$	603.53	194.77	11.3	603.79-603.26=0.53

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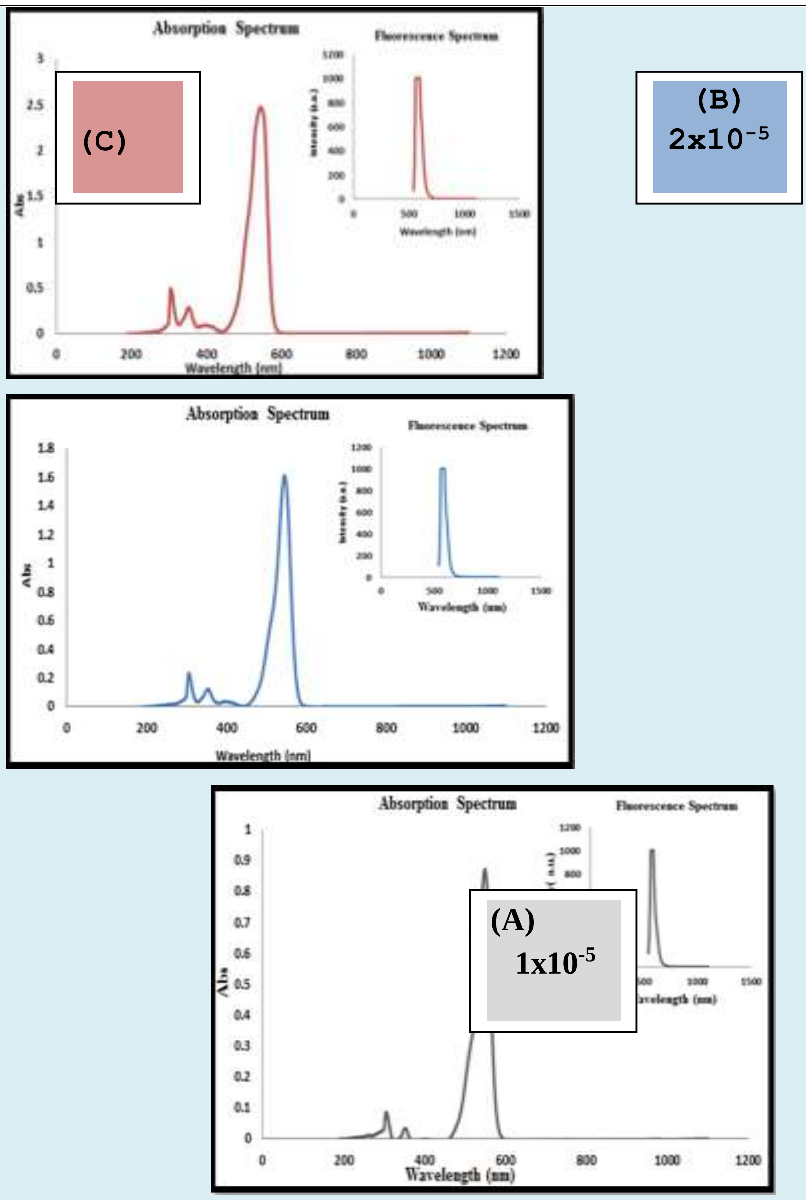
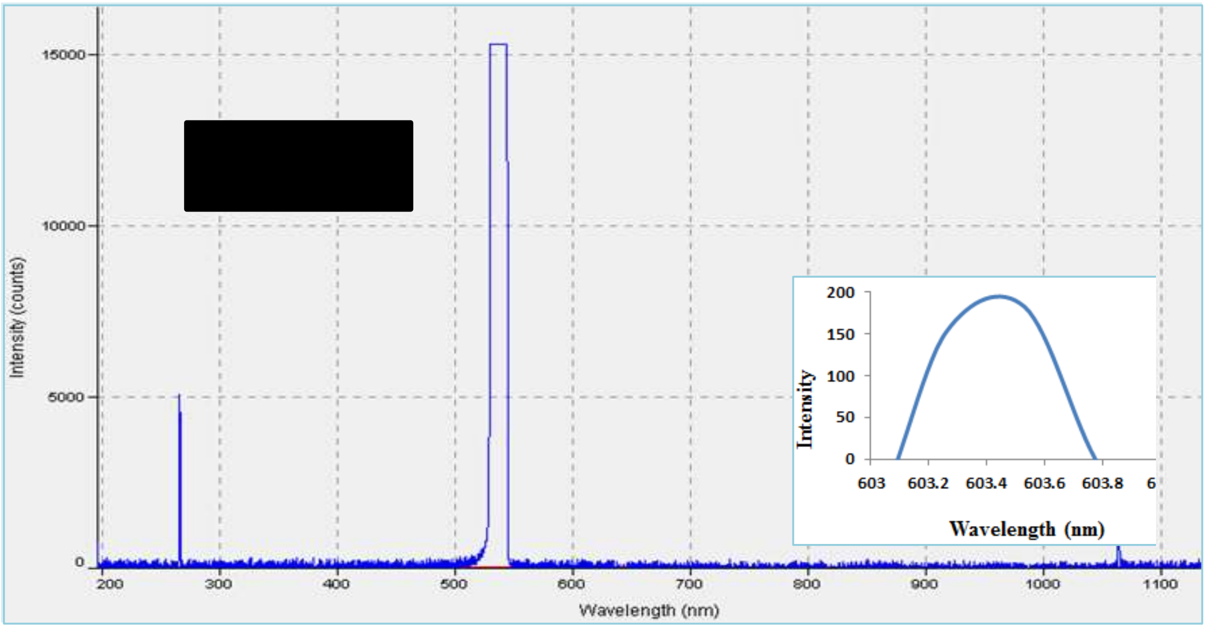
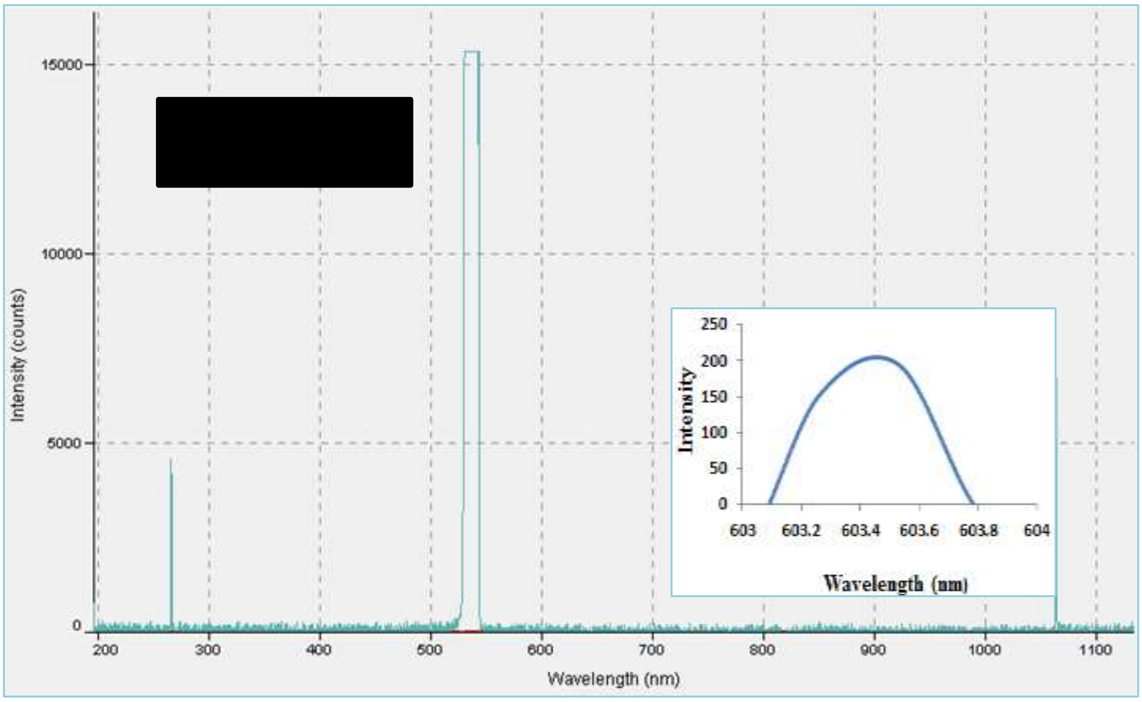
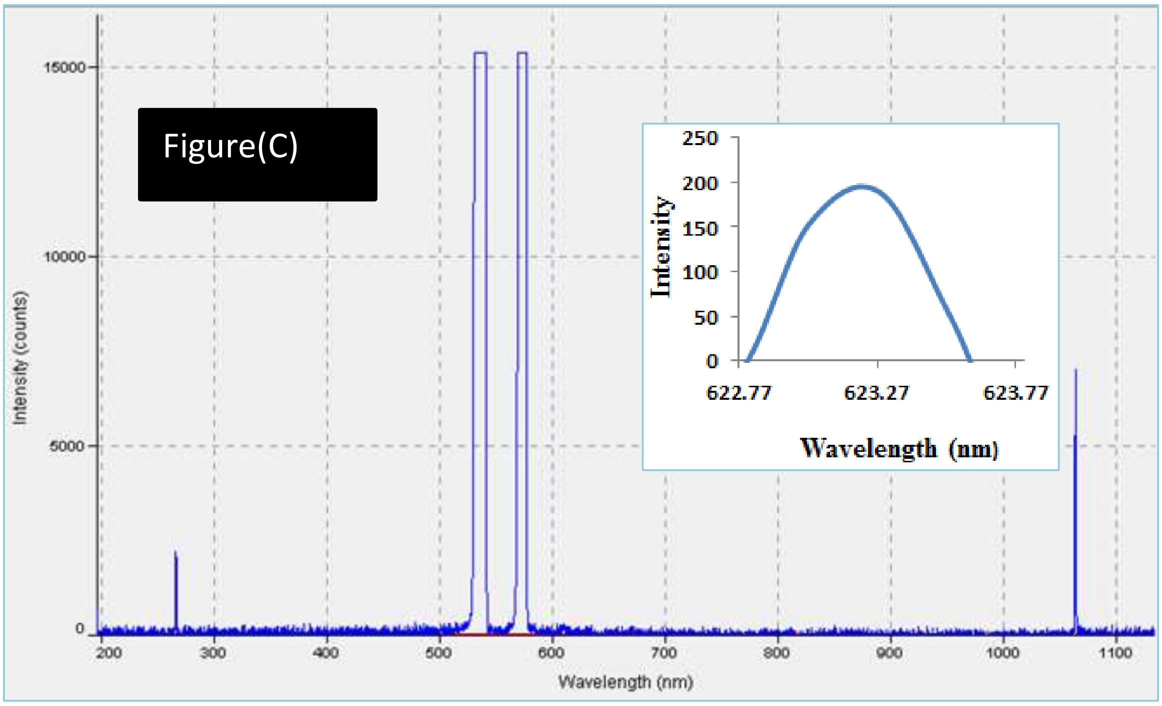


C	$4x10^{-5}$	623.28	188.77	11.9	623.54-623.02=0.52
D	$1x10^{-4}$	623.28	171.27	10.7	623.54-623.02=0.52
E	$5x10^{-4}$	598.32	33.93	12.8	599.1-598.32=0.78
F	$1x10^{-3}$	603.53	202.87	13.9	603.79-603.26=0.53
G	$5x10^{-3}$	619.39	9793.27	15.5	623.8-615.23=8.57


[redacted]
Intensity (counts)
15000
10000
5000
0
200
300
400
500
600
700
800
900
1000
1100
Wavelength (nm)
Intensity
200
150
100
50
0
603
603.2
603.4
603.6
603.8
6
Wavelength (nm)


[redacted]
Intensity (counts)
15000
10000
5000
0
200
300
400
500
600
700
800
900
1000
1100
Wavelength (nm)
Intensity
250
200
150
100
50
0
603
603.2
603.4
603.6
603.8
604
Wavelength (nm)


Figure(C)
Intensity (counts)
15000
10000
5000
0
200
300
400
500
600
700
800
900
1000
1100
Wavelength (nm)
Intensity
250
200
150
100
50
0
622.77
623.27
623.77
Wavelength (nm)

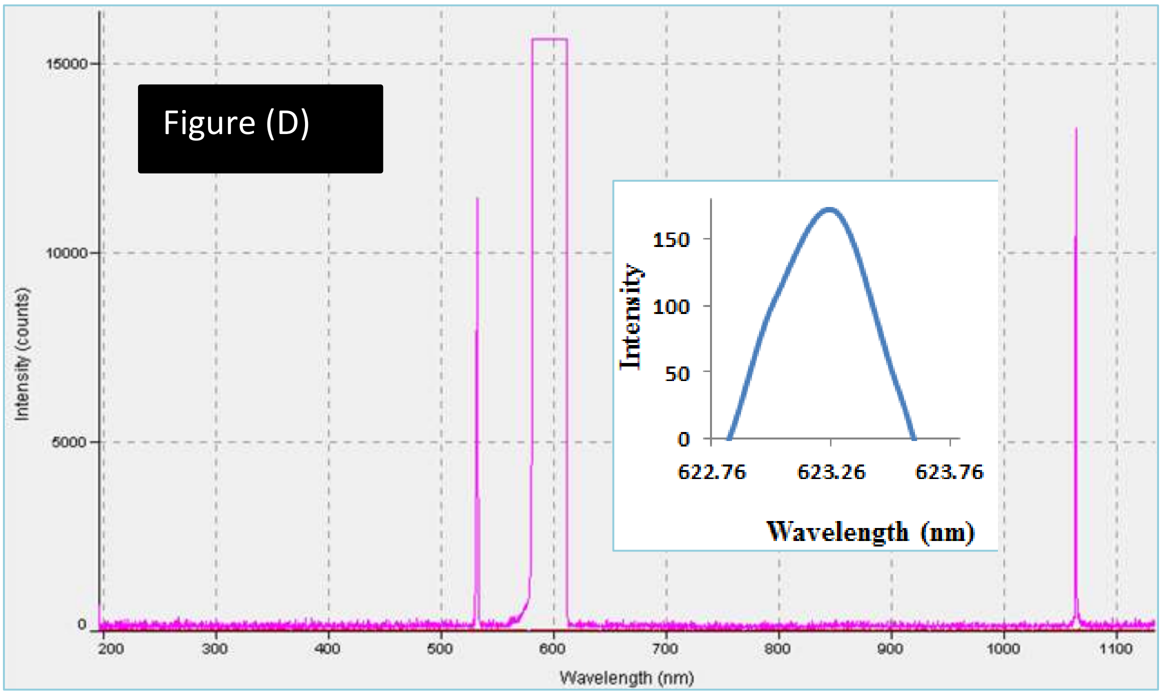
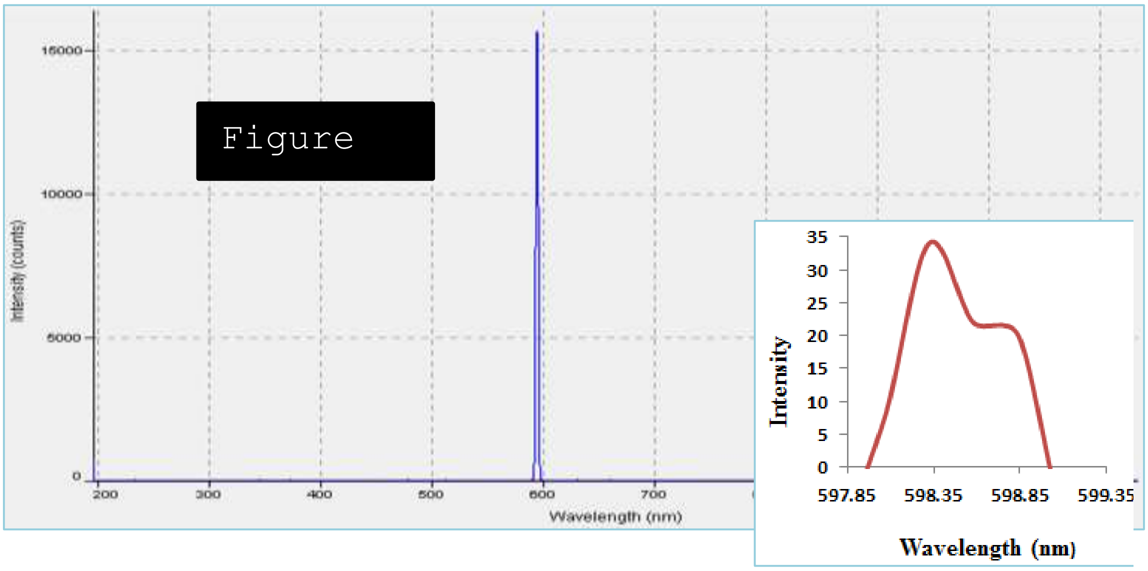
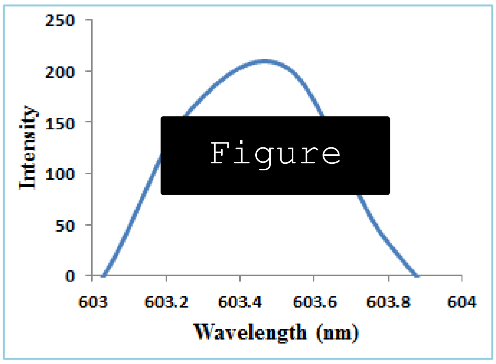
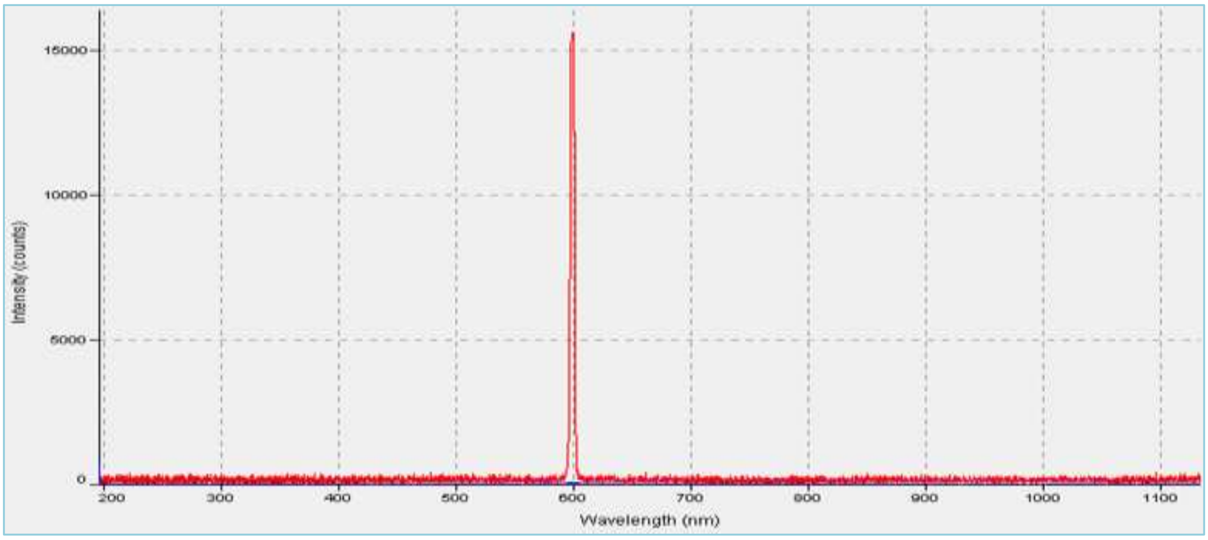


Figure (D)
Intensity (counts)
15000
10000
5000
0
200
300
400
500
600
700
800
900
1000
1100
Wavelength (nm)
Intensity
150
100
50
0
622.76
623.26
623.76
Wavelength (nm)







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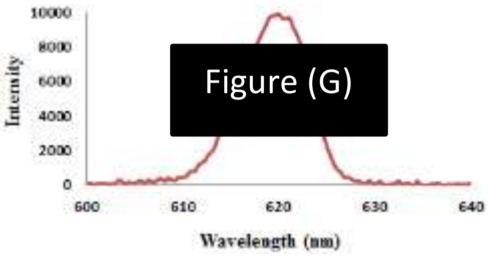


Figure (G)

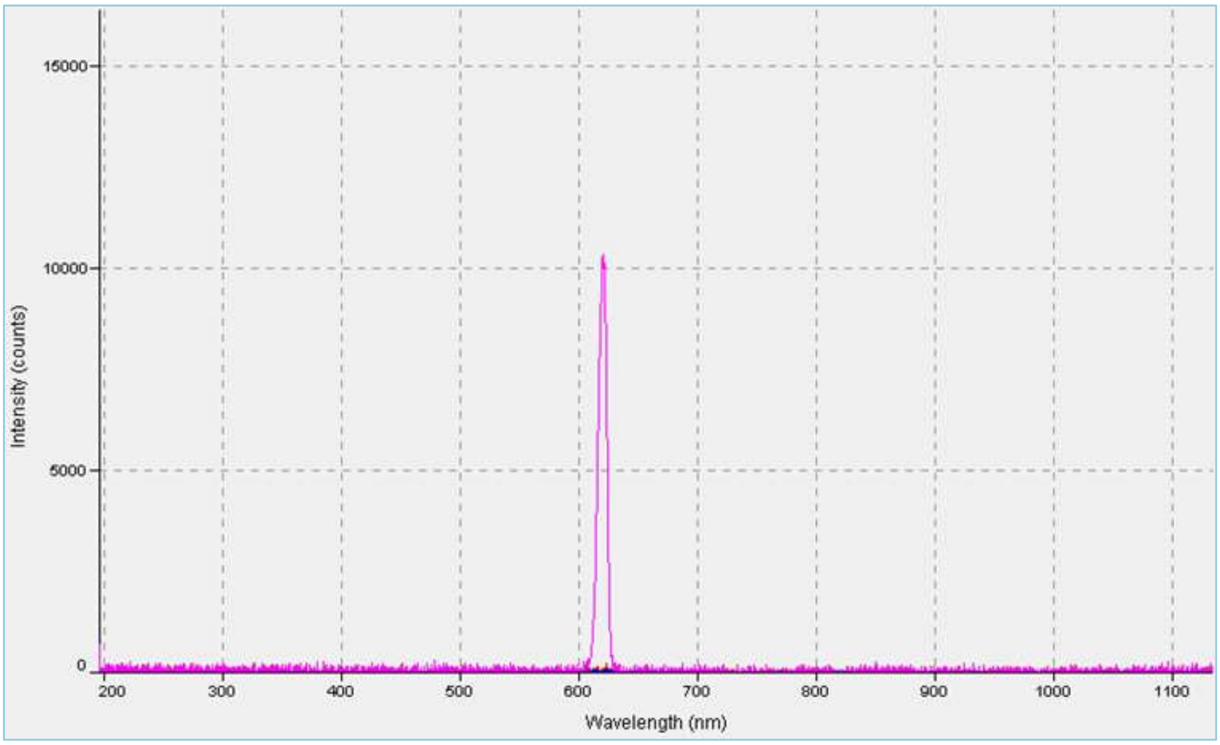
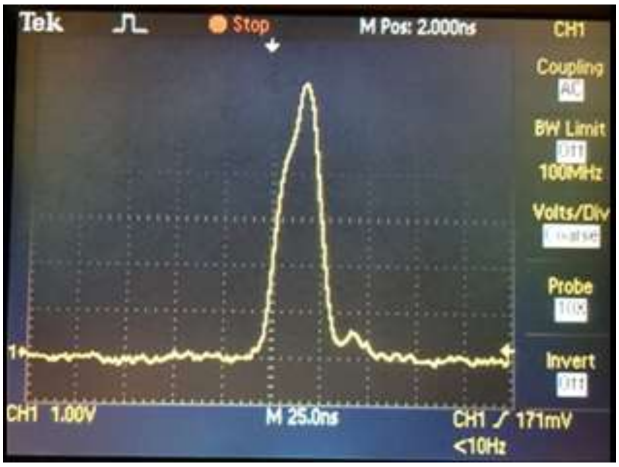


Table 4:The pulse signal on the Oscilloscope

The sign on the scoop
Dye concentration:$5X10^{-3}$ No.1 Pulse time:25.0ns Voltages:(100mV&1.00V)Respectively Frequency:10Hz



Dye concentration:1X10^{-3}

N

o.2

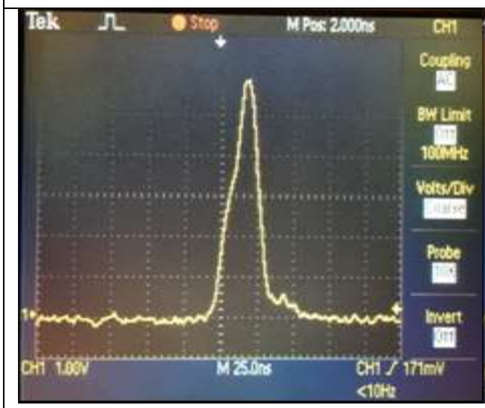
N

o.2

Pulse time:25.0ns

Voltages:(1.00&2.00&5.00)V Respectively

Frequency:10Hz



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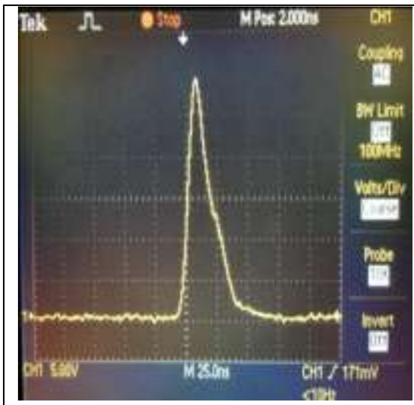


Dye concentration:$5X10^{-4}$

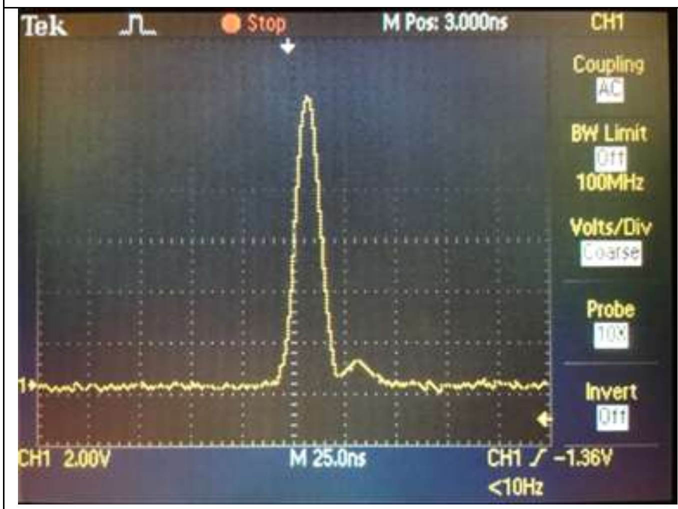
No.3

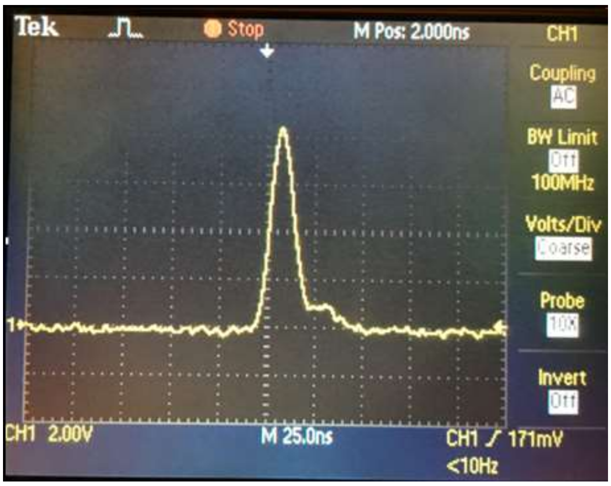
No.3

Pulse time:25.0ns

Voltages:2.00V

Frequency:10Hz





Dye concentration:$1X10^{-4}$

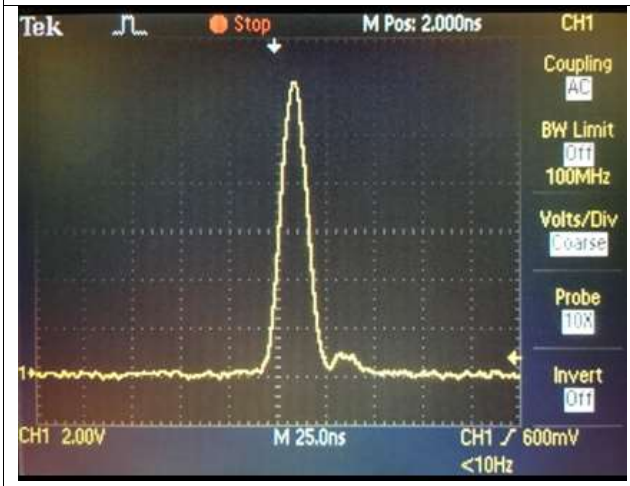
No.4

No.4

Pulse time:25.0ns

Voltages:(2.00&5.00)V Respectively

Frequency:10Hz



Dye concentration:4X10^{-5}

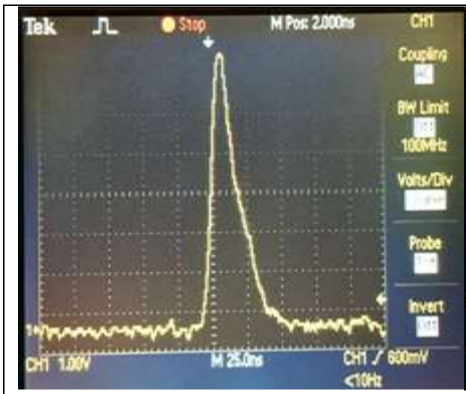
No.5

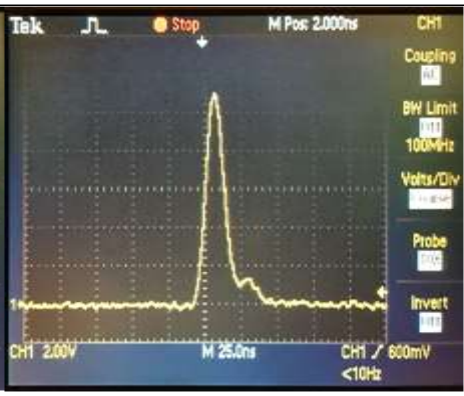
No.5

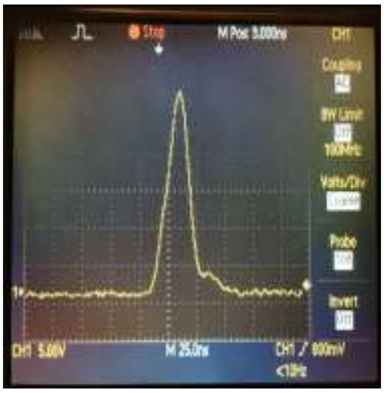
Pulse time:25.0ns

Voltages:(1.00&2.00&5.00)VRespectively

Frequency:10Hz







Dye concentration:$2X10^{-5}$

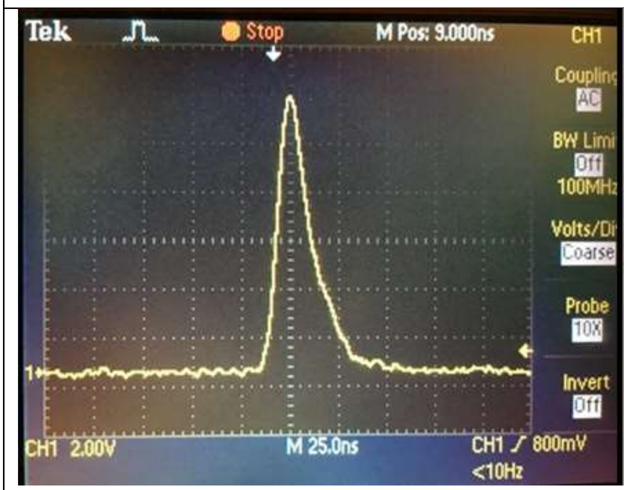
No.6

No.6

Pulse time:25.0ns

Voltages:(2.00&5.00)V Respectively

Frequency:10Hz



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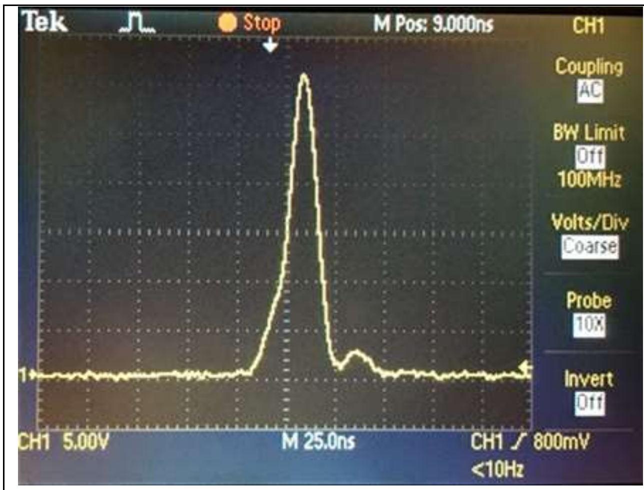


Dye concentration:$1X10^{-5}$

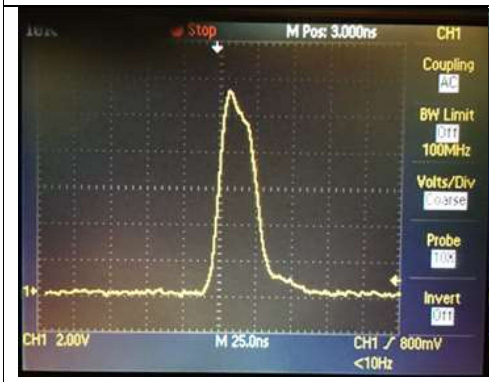
No.7

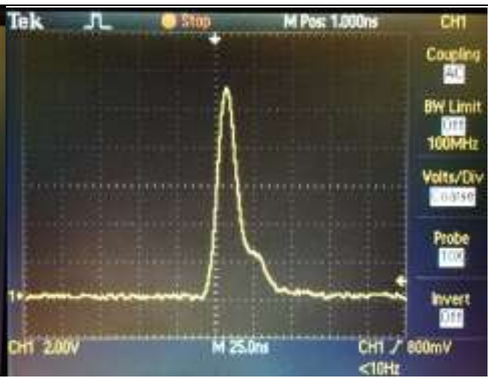
NO.7

Pulse time:25.0ns

Voltages:2.00V

Frequency:10Hz





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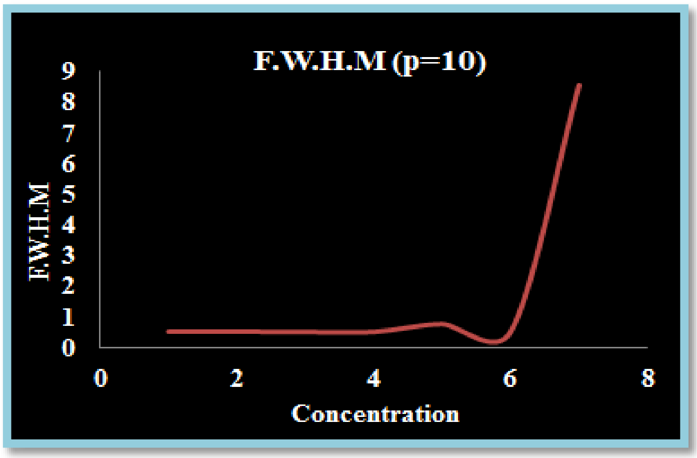

Fig.5.The relationship between concentration and F.W.H.M at constant SHG Nd: YAG Input Energy (35.2mJ).

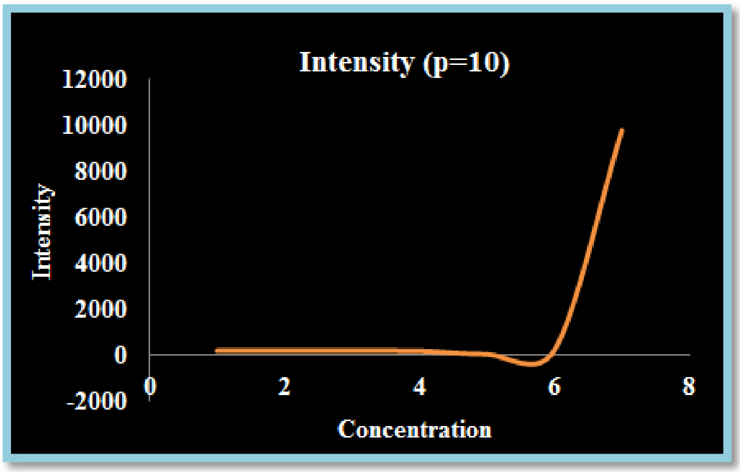

Fig.6.The relationship between concentration and Intensity at constant SHG Nd: YAG Input Energy (35.2mJ).

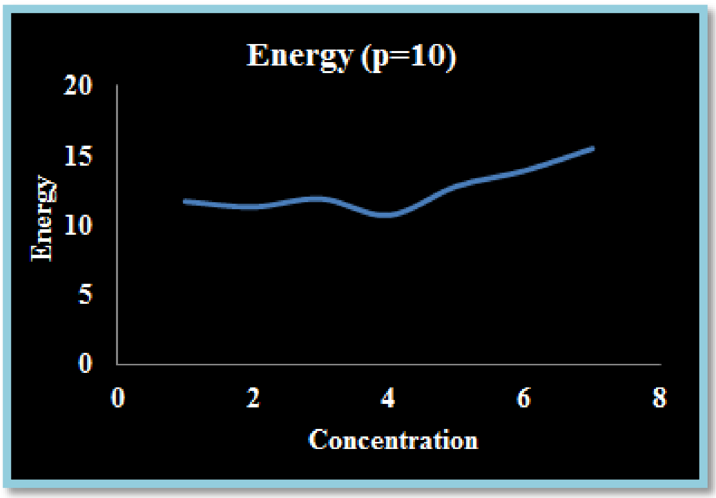

Fig.7. The relationship between concentration and DYE Output Energy at constant SHG Nd: YAG Input Energy (35.2mJ).

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Table (5):The values energy conversion efficiency for different concentrations at input energy maximum

Dye :RB

Power:10

Concentration (M)	SHGNd:YAGInputEnergy (mJ)	DYEOutputEnergy (mJ)	Energy Conversion efficiency $\%E_{ff}=(E_{out}/E_{in})\,x100$
$1x10^{-5}$	35.2	11.7	E_{ff}=(11.7 mJ/35.2 mJ)x100=33.23%
$2x10^{-5}$	35.2	11.3	E_{ff}=(11.3 /35.2 mJ) x100=32.10%
$4x10^{-5}$	35.2	11.9	E_{ff}=(11.9 /35.2 mJ) x100=33.80%
$1x10^{-4}$	35.2	10.7	E_{ff}=(10.7 /35.2 mJ) x100=30.39 %
$5x10^{-4}$	35.2	12.8	E_{ff}=(12.8 /35.2 mJ) x100=36.36%
$1x10^{-3}$	35.2	13.9	Eff=(13.9 /35.2 mJ) x100=39.48%
$5x10^{-3}$	35.2	15.5	Eff=(15.5 /35.2 mJ) x100=44.03%

Dye :RB

Power:10

Concentration (M)	SHGNd:YAGInputEnergy (mJ)	DYEOutputEnergy (mJ)	Energy Conversion efficiency $\%E_{ff}=(E_{out}/E_{in})\,x100$
$1x10^{-5}$	35.2	11.7	E_{ff}=(11.7 mJ/35.2 mJ)x100=33.23%
$2x10^{-5}$	35.2	11.3	E_{ff}=(11.3 /35.2 mJ) x100=32.10%
$4x10^{-5}$	35.2	11.9	E_{ff}=(11.9 /35.2 mJ) x100=33.80%
$1x10^{-4}$	35.2	10.7	E_{ff}=(10.7 /35.2 mJ) x100=30.39 %
$5x10^{-4}$	35.2	12.8	E_{ff}=(12.8 /35.2 mJ) x100=36.36%
$1x10^{-3}$	35.2	13.9	Eff=(13.9 /35.2 mJ) x100=39.48%
$5x10^{-3}$	35.2	15.5	Eff=(15.5 /35.2 mJ) x100=44.03%

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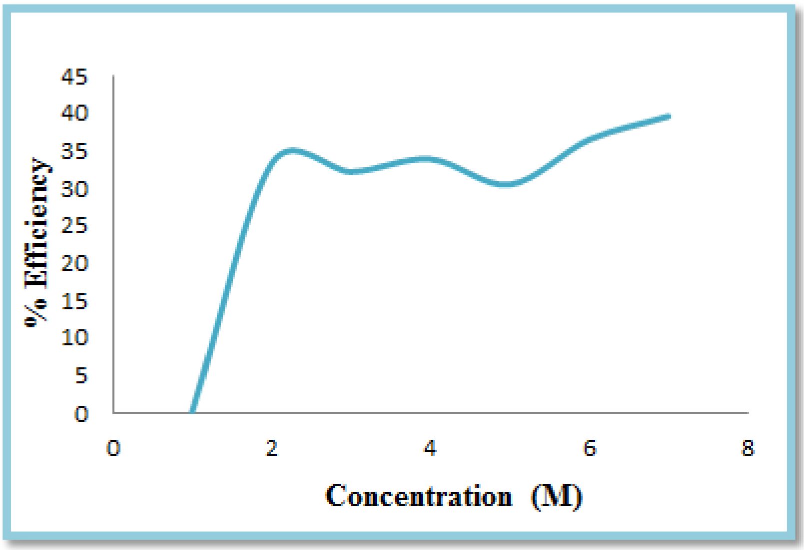

Fig.8. The relationship between concentration and Energy Conversion efficiency at constant SHG Nd: YAG Input Energy (35.2mJ**).**

V. CONCLUSIONS

Until now , laser dye plays an important role in many applications and is the best choice for high power,high repetition rate, high F.W.H.M, narrowband tunable emission in the visible spectrum.Through practical results, we conclude the following:

1- Thefluorescence spectrum shifted to red shift (longer wavelength) with increasing the concentration and the absorption spectrum shifted to blue shift (short wavelength)

2- The stock shift of RB dye increase with increasing the concentration

3- The intensity of the absorption spectra increases with greater concentration relative to the dye solution.

4-The increased F.W.H.M with concentration increases , Where the change in focus affects the full width at half the maximum (FWHM is the difference between two half-height values) where F.W.H.M = 8.57 nm was obtained at the highest concentration.

5-The increased dye output Energy with concentration increases , where dye output Energy = 15.5 mJ was obtained at the highest concentration (5x10-3) mole/l.

6- The increased Energy Conversion efficiency with concentration increases of RB , where Efficiency = 44.03 % was obtained at the highest concentration

7- When the pulse signal is taken on the oscilloscope with the concentration change for the same dye, only the voltages are changed and the pulse time and frequency remain constant at SHG Nd: YAG Input Energy (35.2mJ).

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